

A scenario-based modelling framework for projecting COVID-19 infections and deaths

Presentation to the B.C. COVID-19 Modelling Group

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In my presentation today -

1. Present a general framework for forecasting COVID-19 infections and deaths
2. Demonstrate using a simple infection/death growth model
→ *Canada and 4 provinces*

Looking for feedback on both!

Challenges forecasting for COVID-19

“All models are wrong, some are useful”

-Bonnie Henry

What makes a model useful?

→ *It must be “actionable” by decision makers*

Model delivery is as important
as the underlying model

What makes for effective COVID-19 model delivery?

- Open-science models
- Real-time forecasts
- Interactive “what-if” policy gaming
- Rapid deployment

Our contribution...

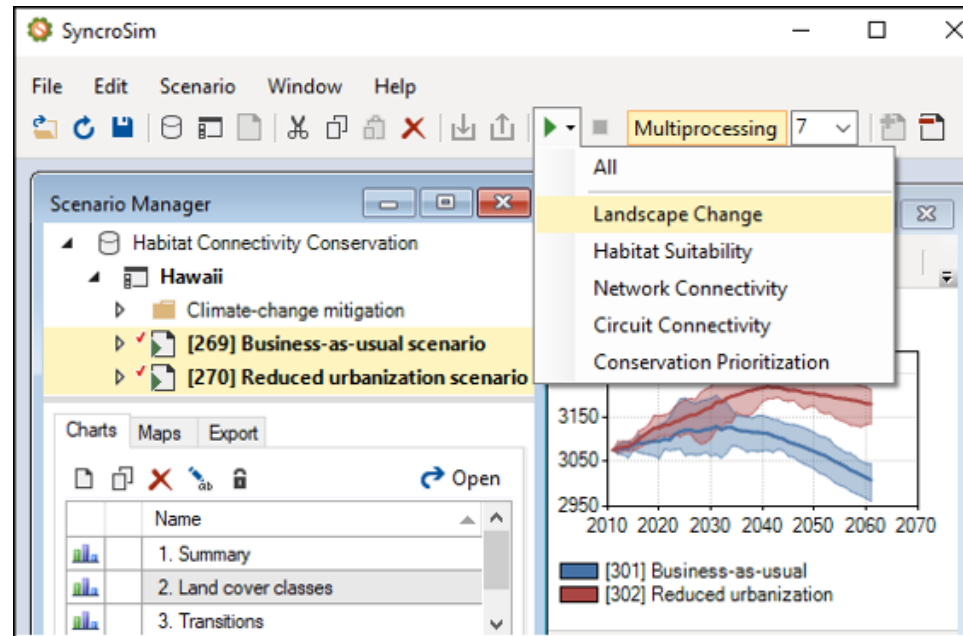
Develop a **general framework** for
COVID-19 modelling

that leverages our existing
SyncroSim software platform

to **deliver models** to decision-makers

What is SyncroSim?

- Monte Carlo simulator
- Automates scenario data management



- 10+ years of development
(for ecological models)

- Free download:

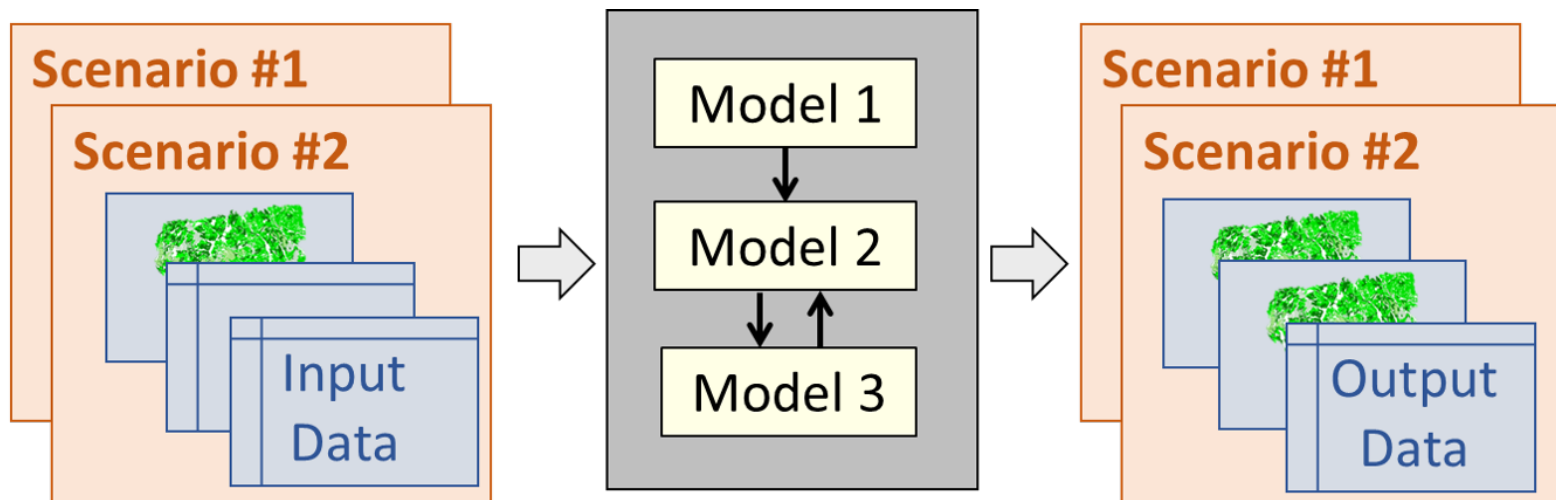
www.syncrosim.com

Key Sponsors:



What is SyncroSim?

- Support model & data “pipelines”
- Models written in any language
→ *e.g. R, Python, C# & executables*
- User interface and full command-line API
→ *e.g. rsyncrosim R package*



What is SyncroSim?

```
library(rsyncrosim)      # Load SyncroSim R package
myScenario = scenario() # Get the SyncroSim scenario that is currently running

# Load scenario's input datasheet from SyncroSim library into R dataframe
myInputDataframe = datasheet(myScenario, name="helloworld_InputDatasheet")

# Extract model inputs from this R dataframe and then do calculations
x = myInputDataframe$x
a = myInputDataframe$a
y = x * a

# Setup an empty R dataframe ready to accept output in SyncroSim datasheet format
myOutputDataframe = datasheet(myScenario, name="helloworld_OutputDatasheet")

# Copy output into this R dataframe
myOutputDataframe[1:length(y),"y"] = y

# Save this R dataframe back to the SyncroSim library's output datasheet
saveDatasheet(myScenario, data=myOutputDataframe, name="helloworld_OutputDatasheet")
```

Start with a model

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```

Add Input & Output Tables

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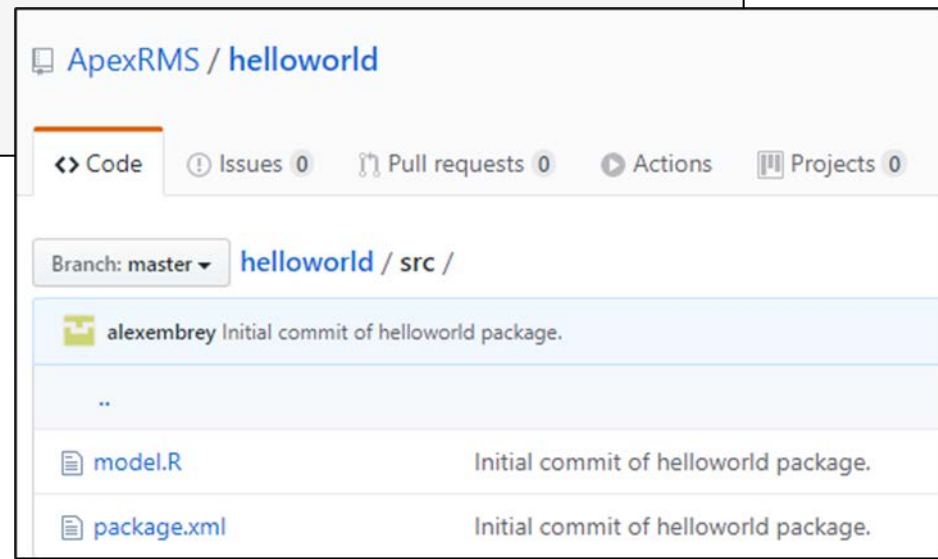
Connect to SyncroSim

What is SyncroSim?

```
<datafeed
  name="InputDatafeed"
  displayName="Inputs"
  dataScope="Scenario">
  <datasheets>
    <datasheet name="InputDatasheet">
      <columns>
        <column name="InputDatasheetID" dataType="Integer" isPrimary="True"/>
        <column name="ScenarioID" dataType="Integer"/>
        <column name="x" dataType="Double" displayName="Value for x"/>
        <column name="a" dataType="Integer" displayName="Value for a"/>
      </columns>
    </datasheet>
  </datasheets>
</datafeed>
```

Input
Table

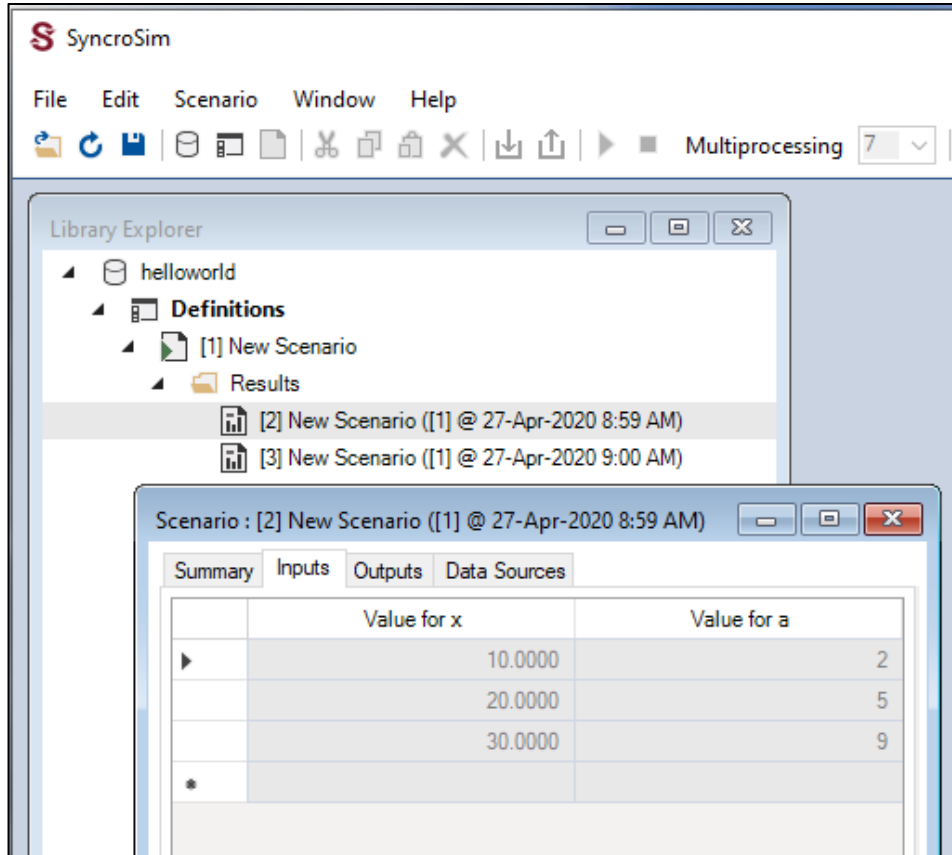
→ Add XML
configuration file
to describe inputs
& outputs



The screenshot shows the GitHub interface for the repository 'ApexRMS / helloworld'. At the top, there are navigation tabs for 'Code', 'Issues 0', 'Pull requests 0', 'Actions', and 'Projects 0'. Below the tabs, the current branch is 'master' and the file path is 'helloworld / src /'. The main content area shows a commit history with the following entries:

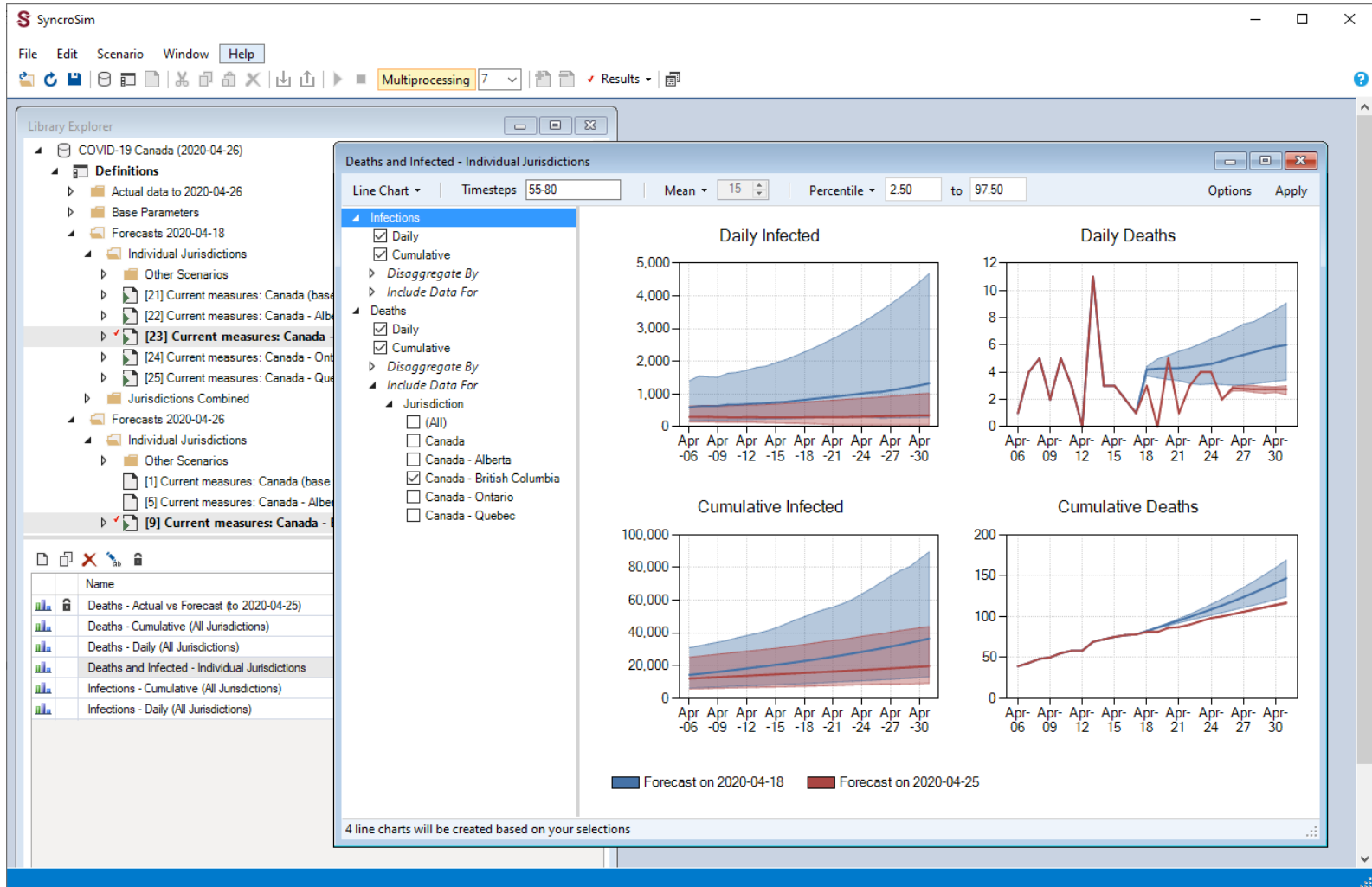
- A commit by 'alexembrey' with the message 'Initial commit of helloworld package.' and a commit hash starting with '..'.
- A file named 'model.R' with the message 'Initial commit of helloworld package.'.
- A file named 'package.xml' with the message 'Initial commit of helloworld package.'.

What is SyncroSim?



→ SyncroSim then automatically tracks all your inputs & outputs...

What is SyncroSim?



... and provides a suite of built-in “what-if” scenario building tools

What is SyncroSim?

The image shows two overlapping screenshots. The background is a GitHub repository page for 'syncrosim/packages'. A red box highlights the text: 'Metadata for registered SyncroSim packages: <http://syncrosim.com>'. Below this, a list of packages is shown, with 'epidemic' highlighted by another red box. The foreground is a 'New Library' dialog box. It has a table of suggested base packages:

Name	Description	Version
demosales	Demo Sales SyncroSim Base Package	1.0.3
dgsim	Simulates demographics of wildlife populations	2.2.8
epidemic	Model of epidemic infections and deaths	1.0.1
helloworld	Hello World Package	1.0.0
stsim	The ST-Sim state-and-transition simulation model	3.2.16

Below the table, there are two template options: 'Empty Library' and 'COVID-19 Canada'. The 'File name' field contains 'covid19-canada.ssim' and the 'Folder' field contains 'C:\Users\colin.daniel\Documents'. 'OK' and 'Cancel' buttons are at the bottom.

→ SyncroSim also support publishing models online as a SyncroSim Package (*through GitHub*)...

What is SyncroSim?

The image shows a screenshot of the SyncroSim packages page and a 'New Library' dialog box. The packages page lists various packages with their descriptions and versions. The 'New Library' dialog box is open, showing a table of base packages and a selection of templates for the 'epidemic' library. The 'COVID-19 Canada' template is highlighted with a red box.

syncrosim / packages

Code Issues 0 Pull requests 0 Actions Projects 0

Metadata for registered SyncroSim packages: <http://syncrosim.com>

Manage topics

50 commits 1 branch 0 packages

Branch: master New pull request

alexembrey Update stsim metadata for v3.2.17 release.

Name	Description	Version
demosales	Demo Sales SyncroSim Base Package	1.0.3
dgsim	Simulates demographics of wildlife populations	2.2.8
epidemic	Model of epidemic infections and deaths	1.0.1
helloworld	Hello World Package	1.0.0
stsim	The ST-Sim state-and-transition simulation model	3.2.16

Select a template for your 'epidemic' library:

Empty Library COVID-19 Canada

File name: covid19-canada.ssim

Folder: C:\Users\colin.daniel\Documents

OK Cancel

... and delivering online parameter updates using SyncroSim Templates

See www.apexrms.com/covid19 for example

Framework case study model:

Forecasting COVID-19 infections and deaths
for Canada and four provinces

Model Approach

- Fits death growth curve
- Similar to the U.S. IMHE¹ model except:
 - *Also calculates infections*
 - *Different approach to fitting growth curves*

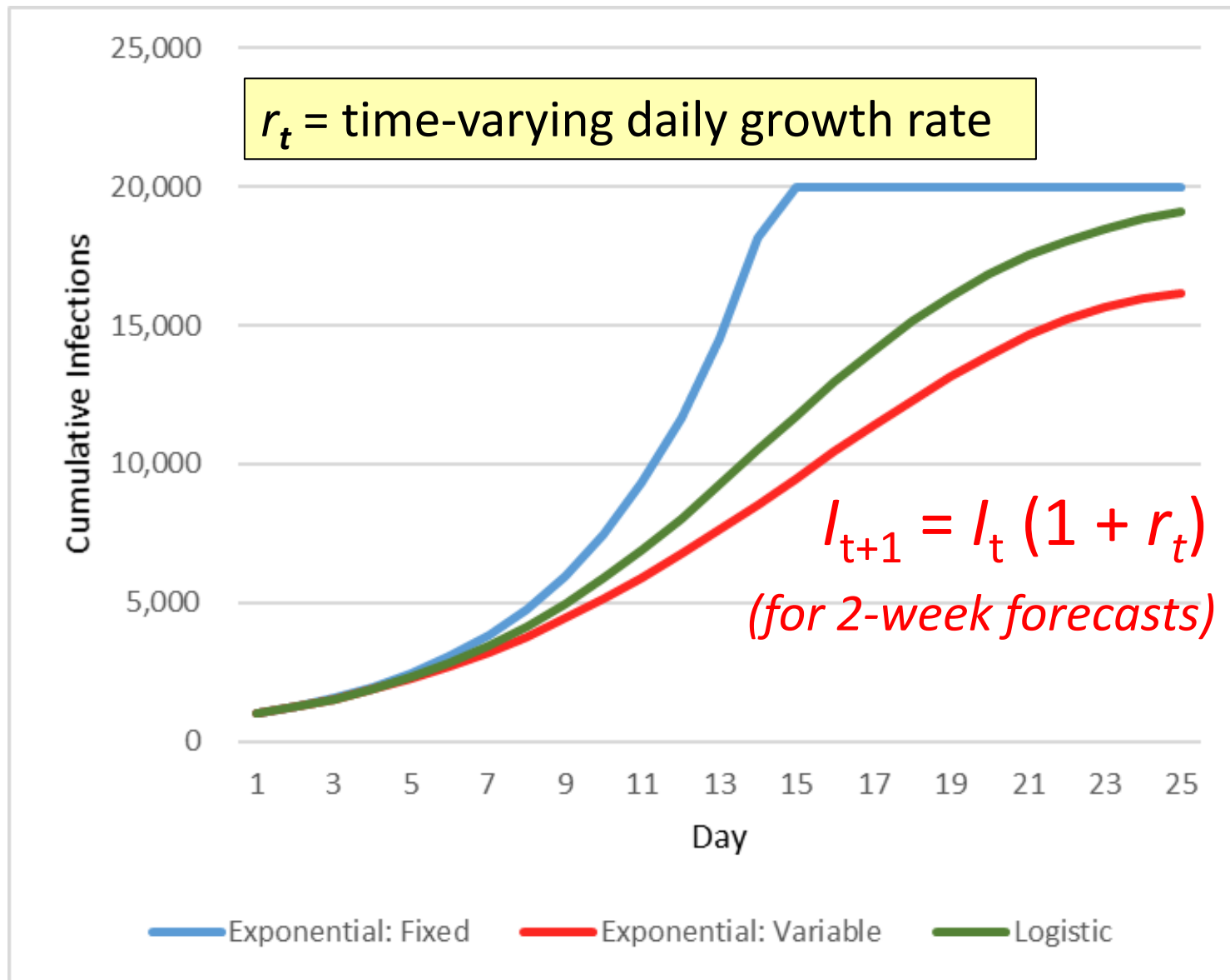
¹ Institute for Health Metrics and Evaluation (IHME) – www.healthdata.org

Step 1: Back-calculate infections from deaths

Daily Infections: $\Delta I_t = I_t - I_{t-1} = D_{t+i} / F_t$

Where I_t = cumulative infections on day t
 F_t = age-standardized infection fatality rate on day t
 i = infection period (incubation + symptoms)

Step 2: Project infections forward in time



Step 3: Calculate future deaths from infections

$$D_t = \Delta I_{t-i} F_{t-i}$$

→ All model inputs are random variables

Model Inputs

1. Age-standardized infection fatality rates:

(Verity et al 2020)

By jurisdiction:

CA: 1.02% (0.55-1.96)

BC: 1.07% (0.58-2.07)

→ sampled as gamma distribution

→ Also modelled base rates X 1.5

Model Inputs

2. Incubation Period:

4.5–5.8 days (Lauer et al 2020)

3. Symptom-to-Death Period:

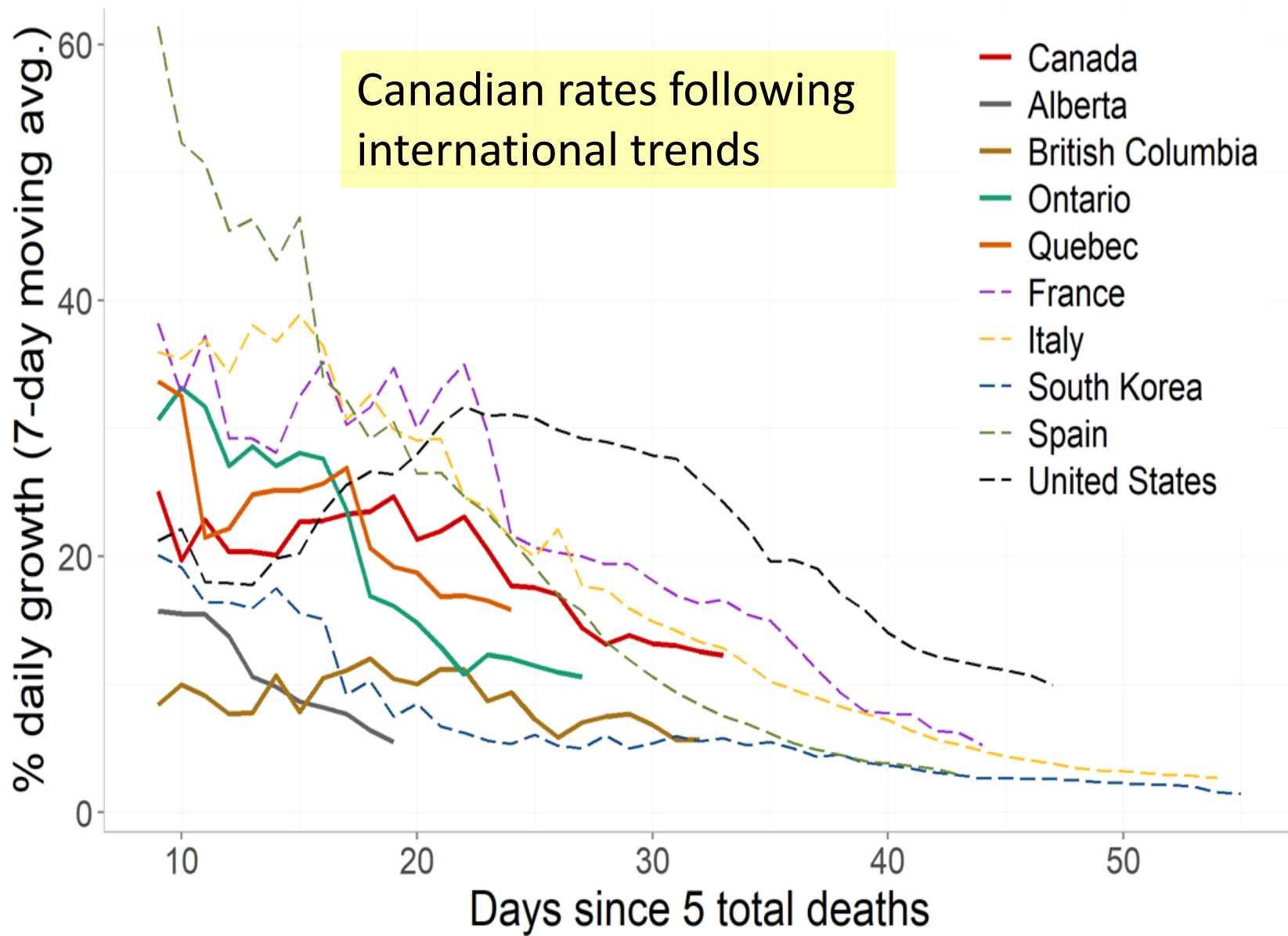
16.9–19.2 days (Verity et al 2020)

→ *Sampled as uniform distributions*

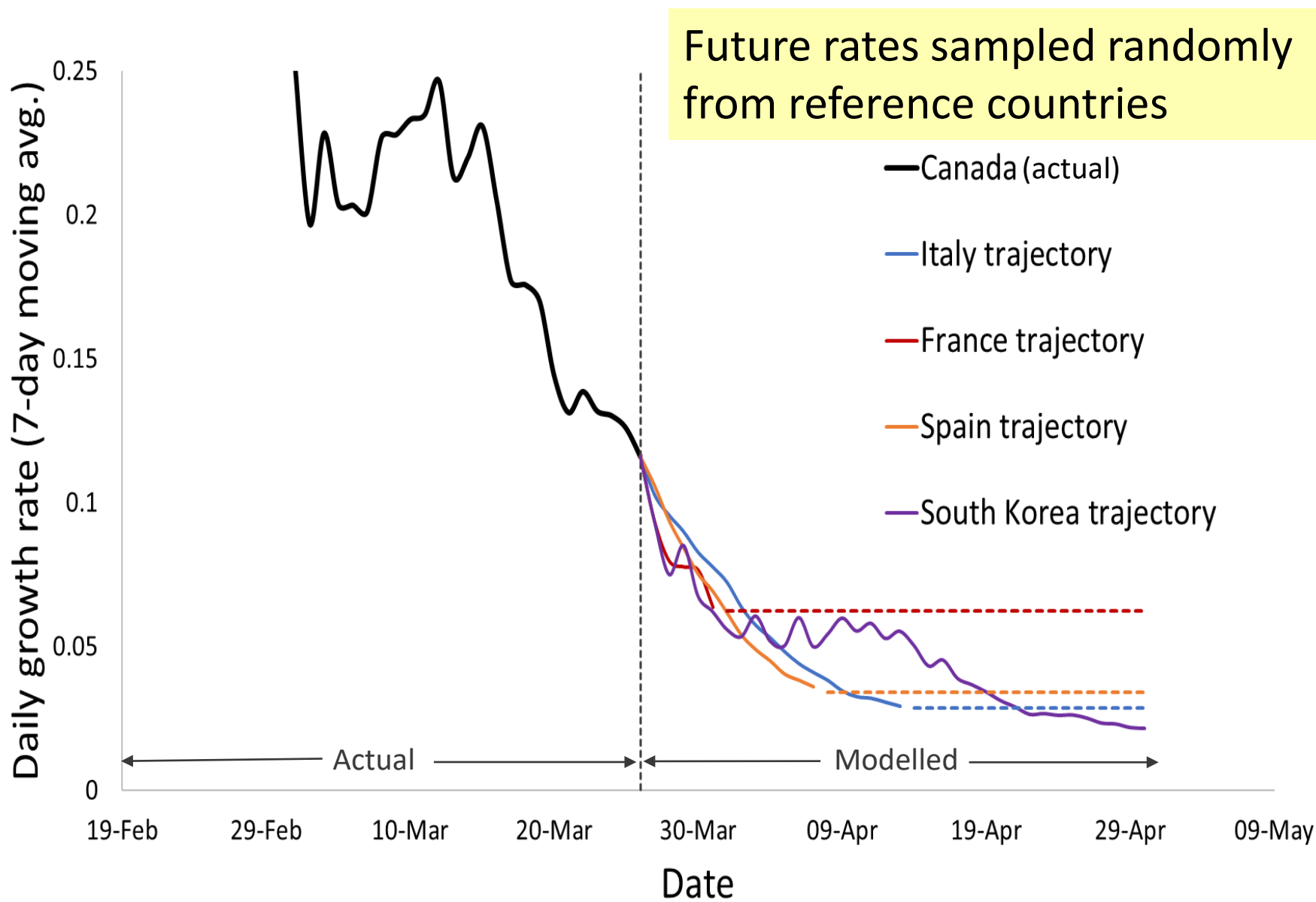
4. Daily Growth Rates:

sampled from reference jurisdictions

Actual cumulative death growth rate up to and including April 17



Modelled cumulative death growth rates for Canada (for Apr 18)



Model Inputs

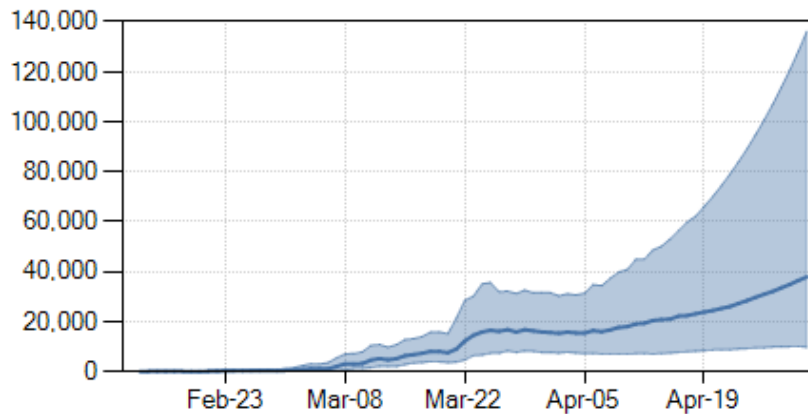
Start Date: Feb 12 (*25 days prior to first death*)

End Date: 14 days after last death

- Forecasts generated daily:
 - *starting April 18 to April 25*
- 1000 Monte Carlo realizations
 - *display 95% MC confidence interval*

April 18 forecast: Canada

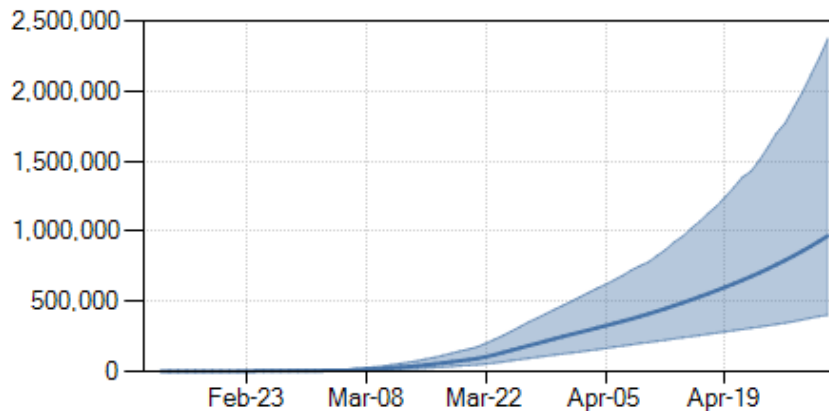
Daily Infected



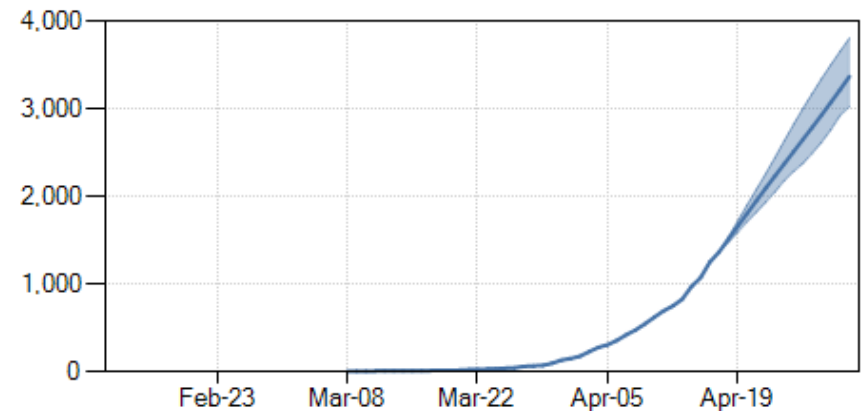
Daily Deaths



Cumulative Infected



Cumulative Deaths

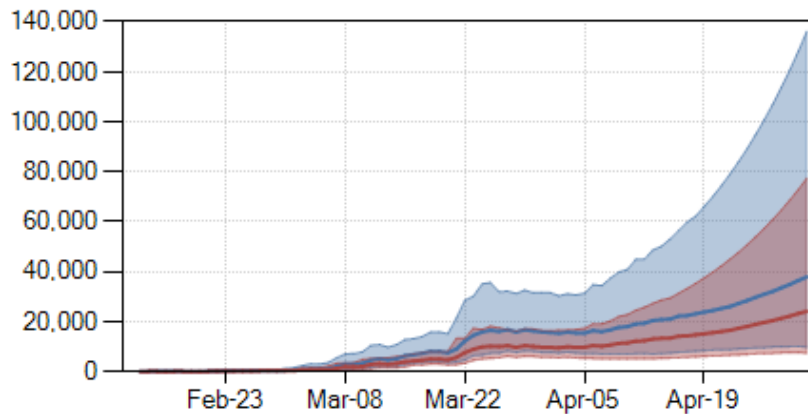


■ Base fatality

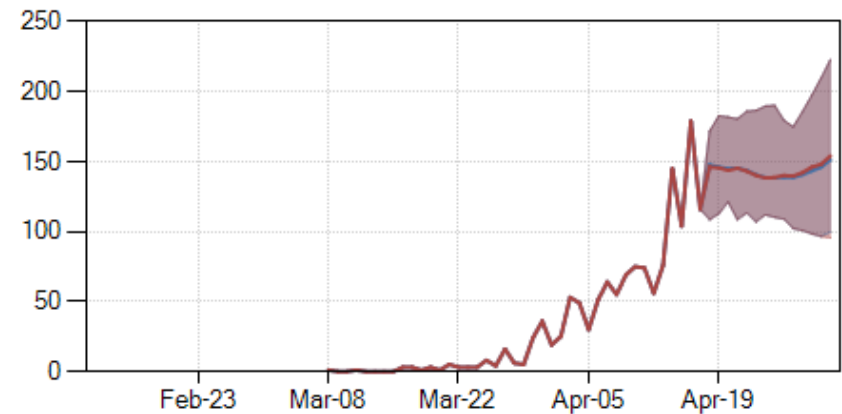
National model projections for infections and deaths made 7 days ago

April 18 forecast: Canada

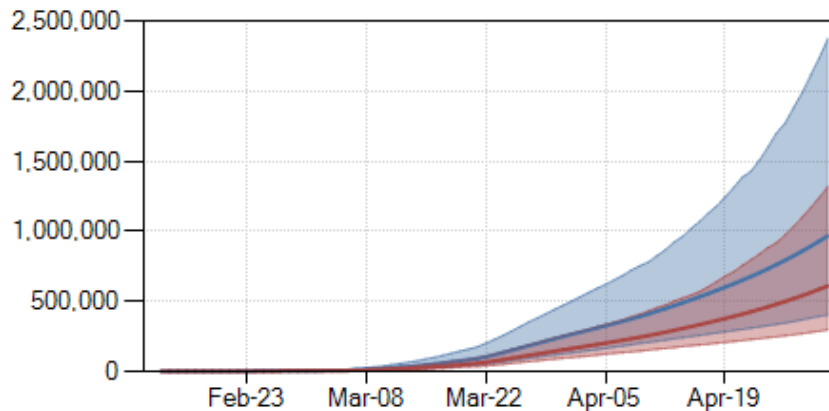
Daily Infected



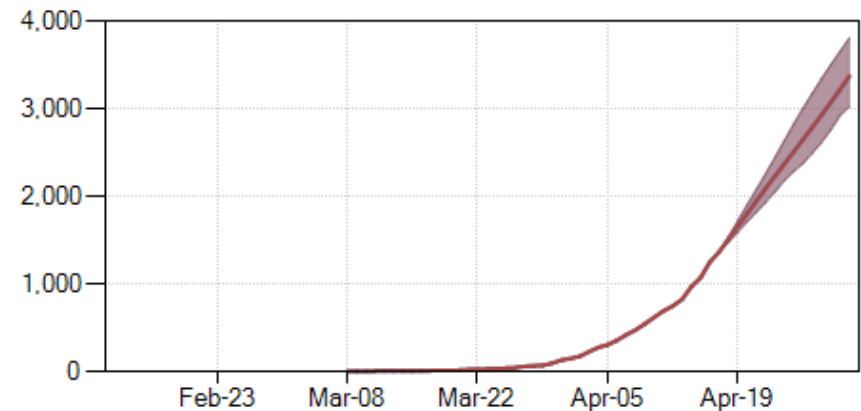
Daily Deaths



Cumulative Infected



Cumulative Deaths



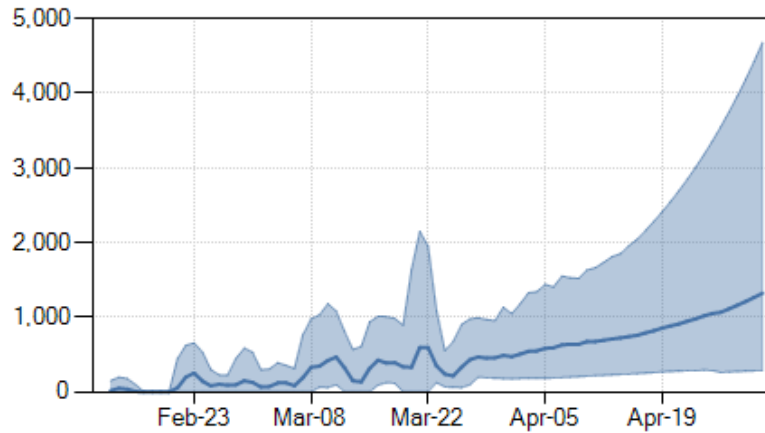
Base fatality

High fatality (base x 1.5)

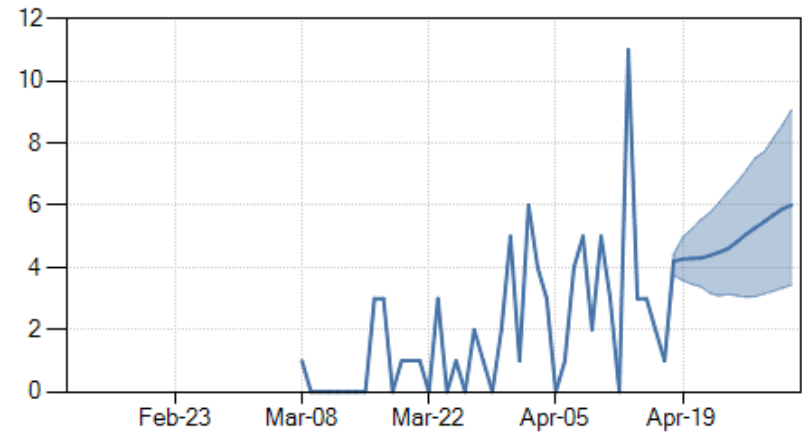
Infection projections are sensitive to fatality rate assumption

April 18 forecast: **British Columbia**

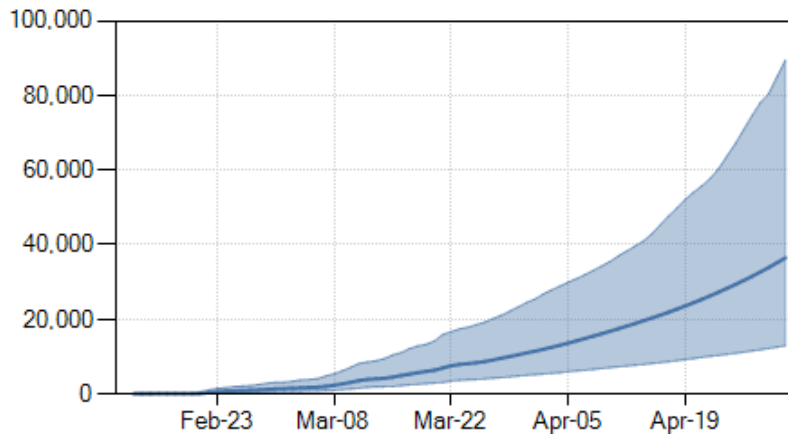
Daily Infected



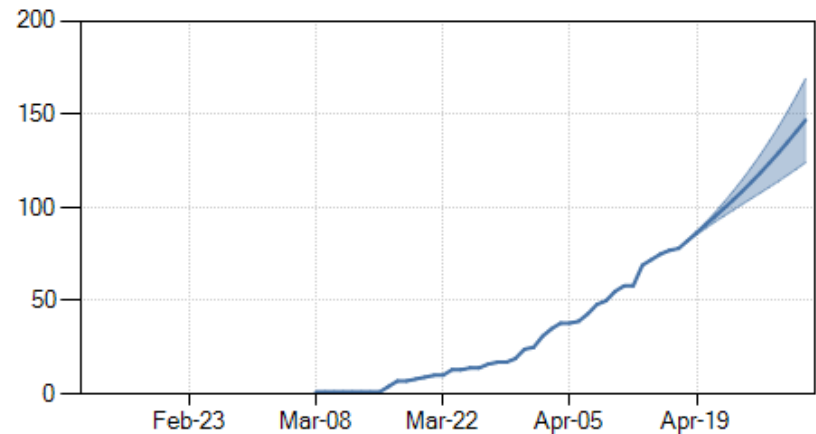
Daily Deaths



Cumulative Infected



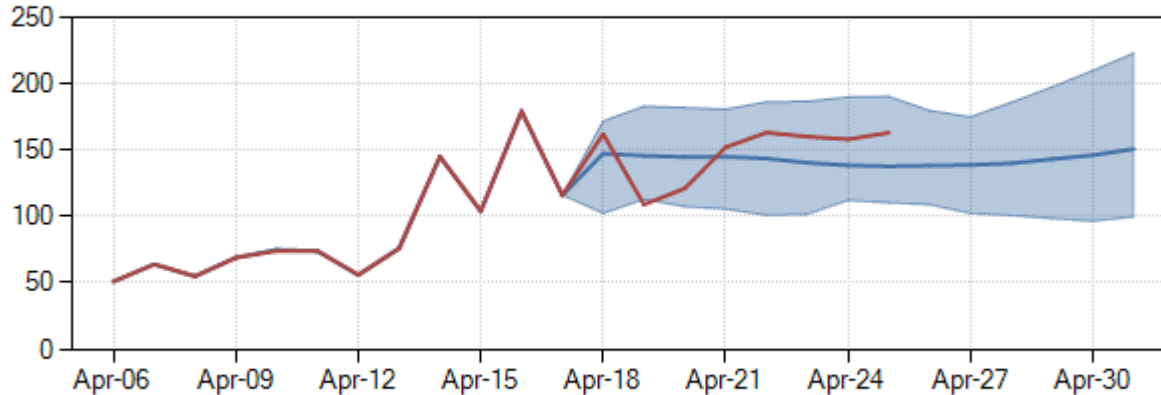
Cumulative Deaths



B.C. projections made 7 days ago

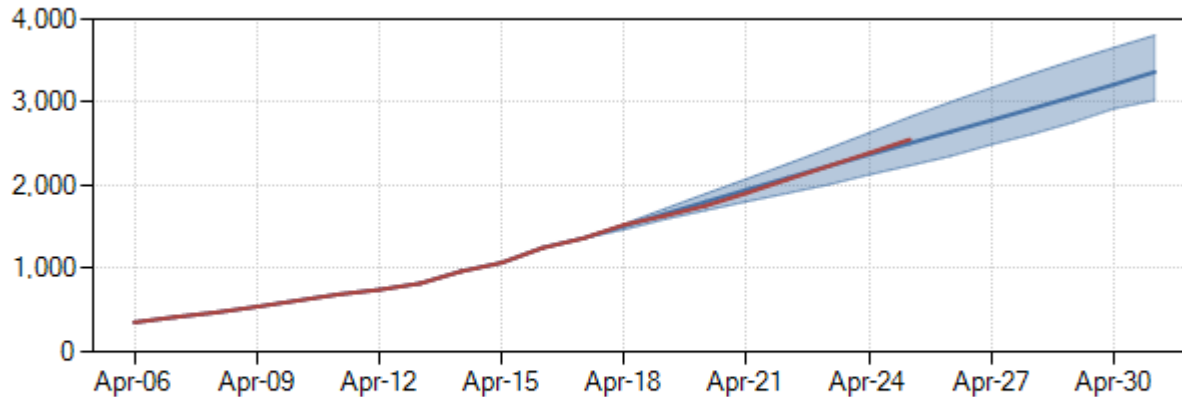
April 18 death forecast vs actual: **Canada**

Daily Deaths
Canada



Actual deaths within 95% confidence interval of national projections for past 7 days

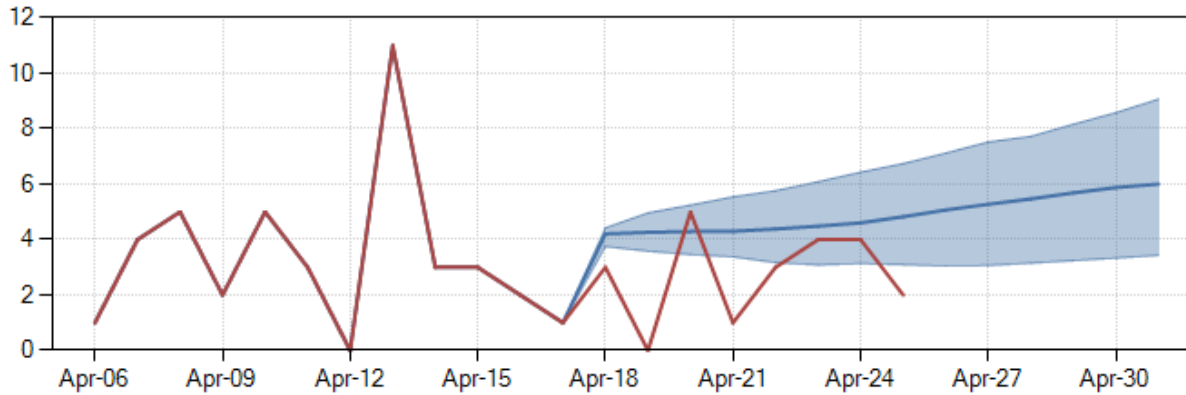
Cumulative Deaths
Canada



Forecast on 2020-04-18 Actual (to 2020-04-25)

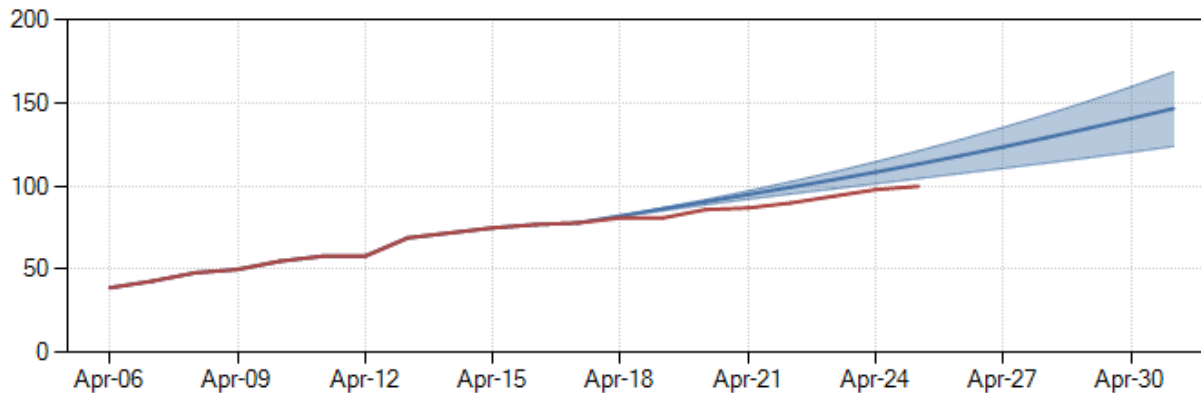
April 18 death forecast vs actual: B.C.

Daily Deaths



For B.C. the model is projecting a bit higher than actual (*due to spike in deaths on Apr 13*)

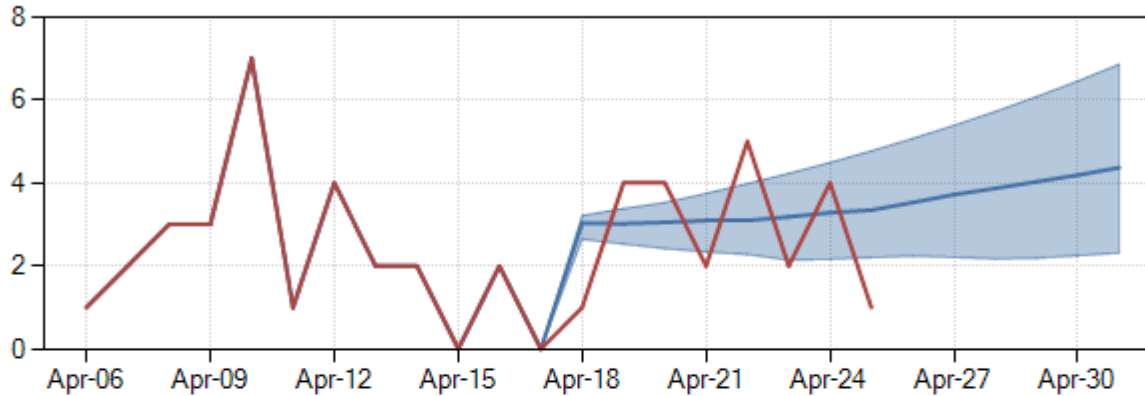
Cumulative Deaths



Forecast on 2020-04-18 Actual (to 2020-04-25)

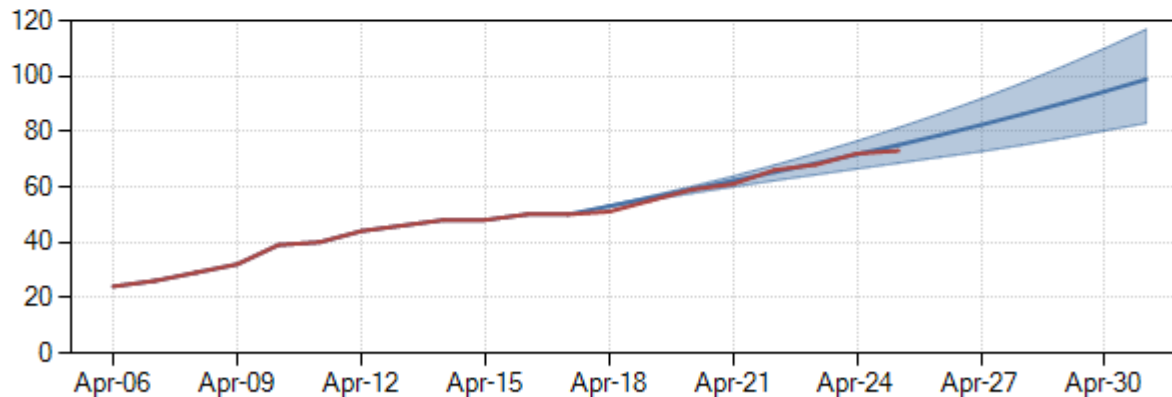
April 18 death forecast vs actual: Alberta

Daily Deaths
Canada - Alberta



Model projections tracking actual deaths for Alberta

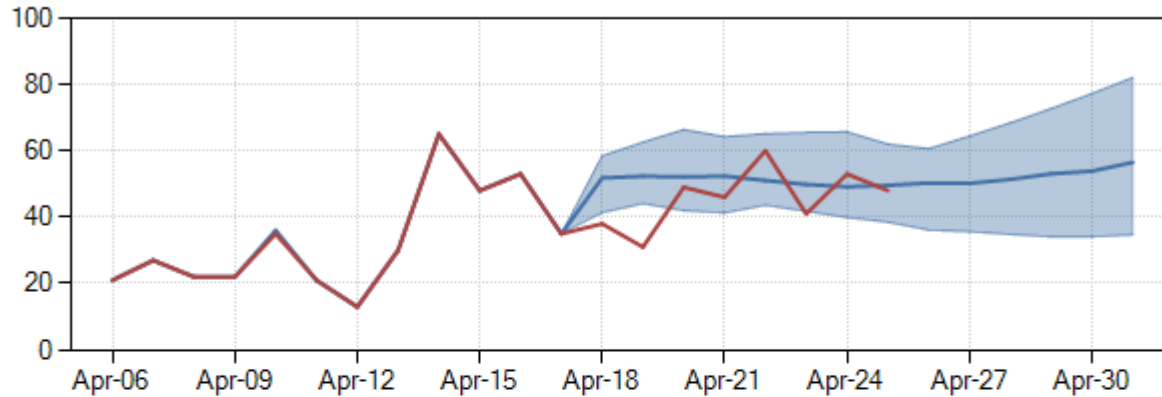
Cumulative Deaths
Canada - Alberta



Forecast on 2020-04-18 Actual (to 2020-04-25)

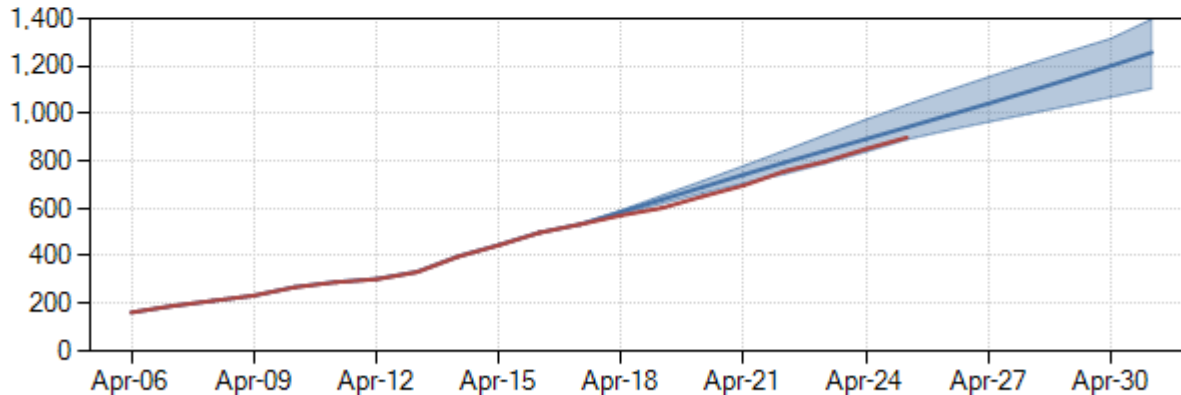
April 18 death forecast vs actual: Ontario

Daily Deaths
Canada - Ontario



Projections also tracking actual for Ontario

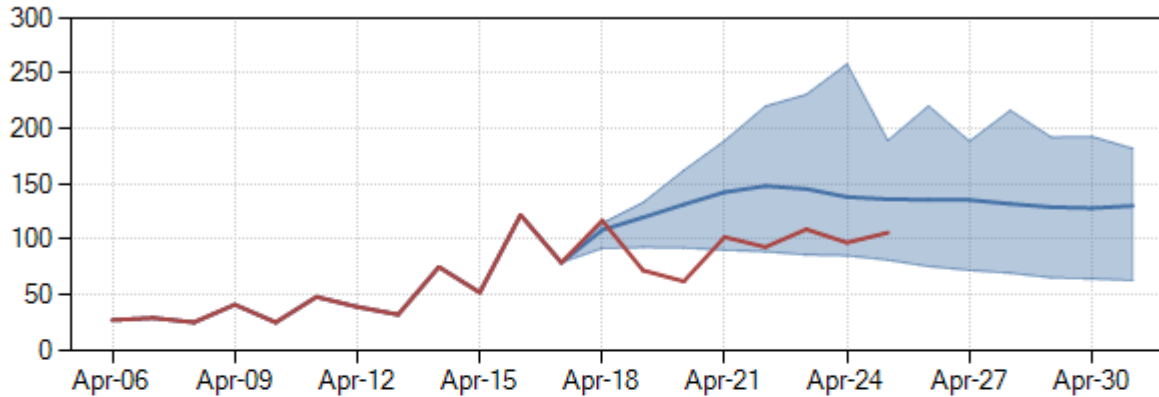
Cumulative Deaths
Canada - Ontario



Forecast on 2020-04-18 Actual (to 2020-04-25)

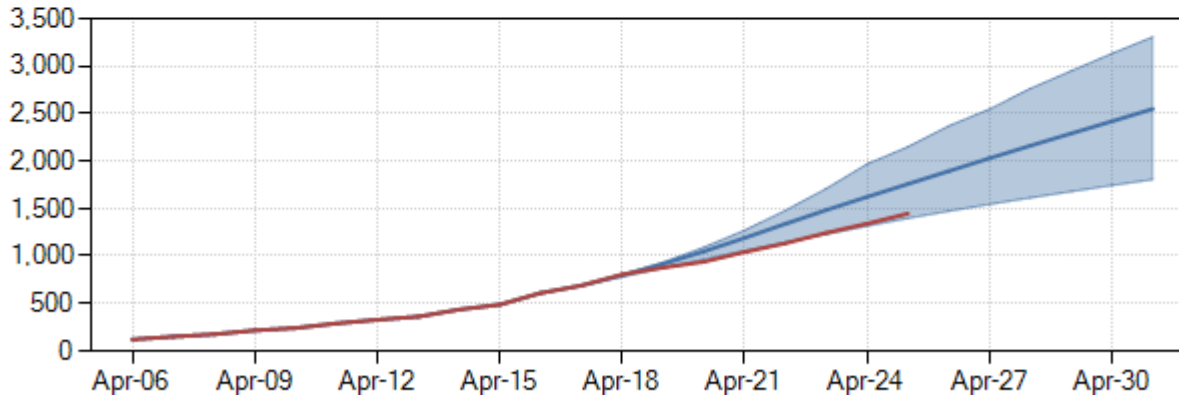
April 18 death forecast vs actual: Quebec

Daily Deaths
Canada - Quebec



Projections tracking for Quebec (*but also a bit high*)

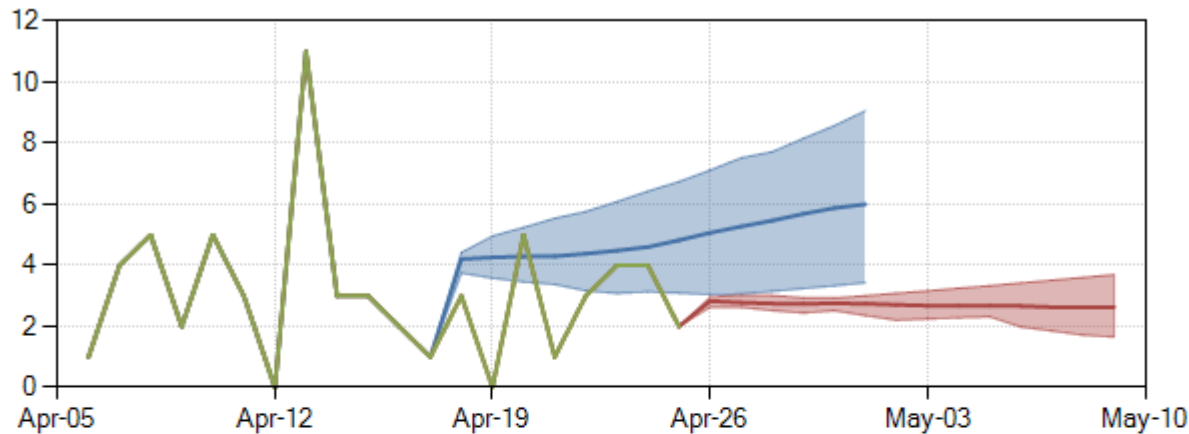
Cumulative Deaths
Canada - Quebec



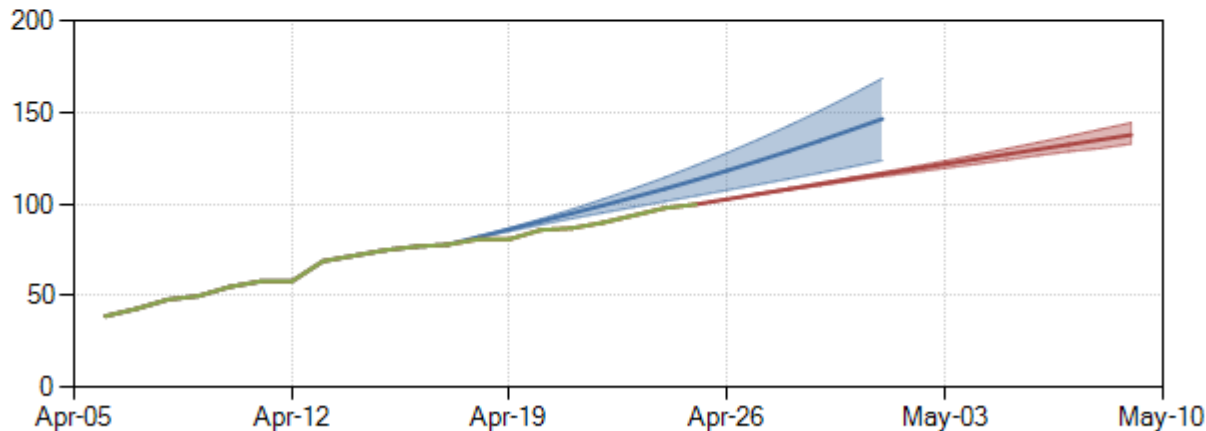
Forecast on 2020-04-18 Actual (to 2020-04-25)

April 18 vs April 25 death forecasts: B.C.

Daily Deaths



Cumulative Deaths

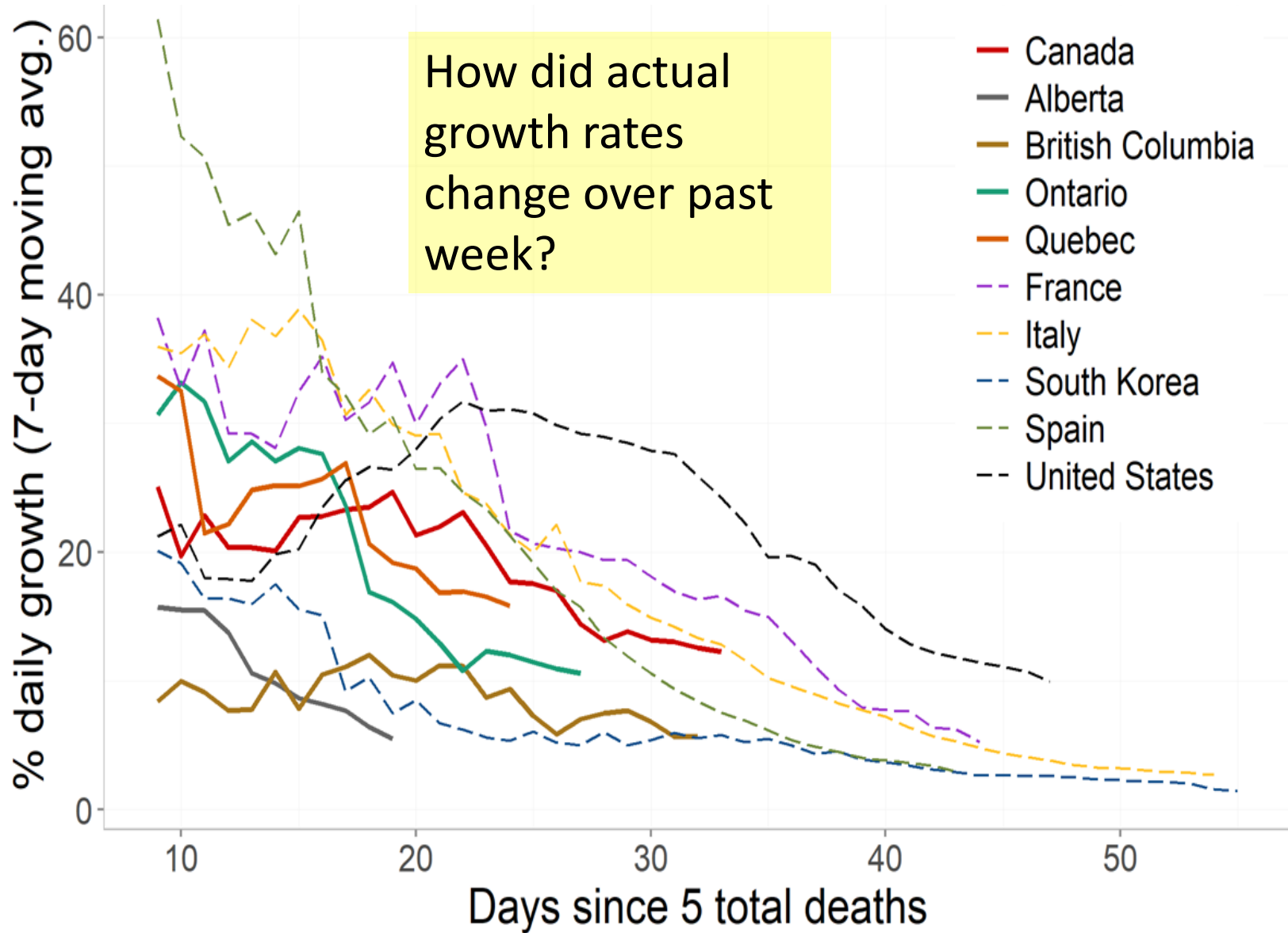


Forecast on 2020-04-18 Forecast on 2020-04-25 Actual (to 2020-04-25)

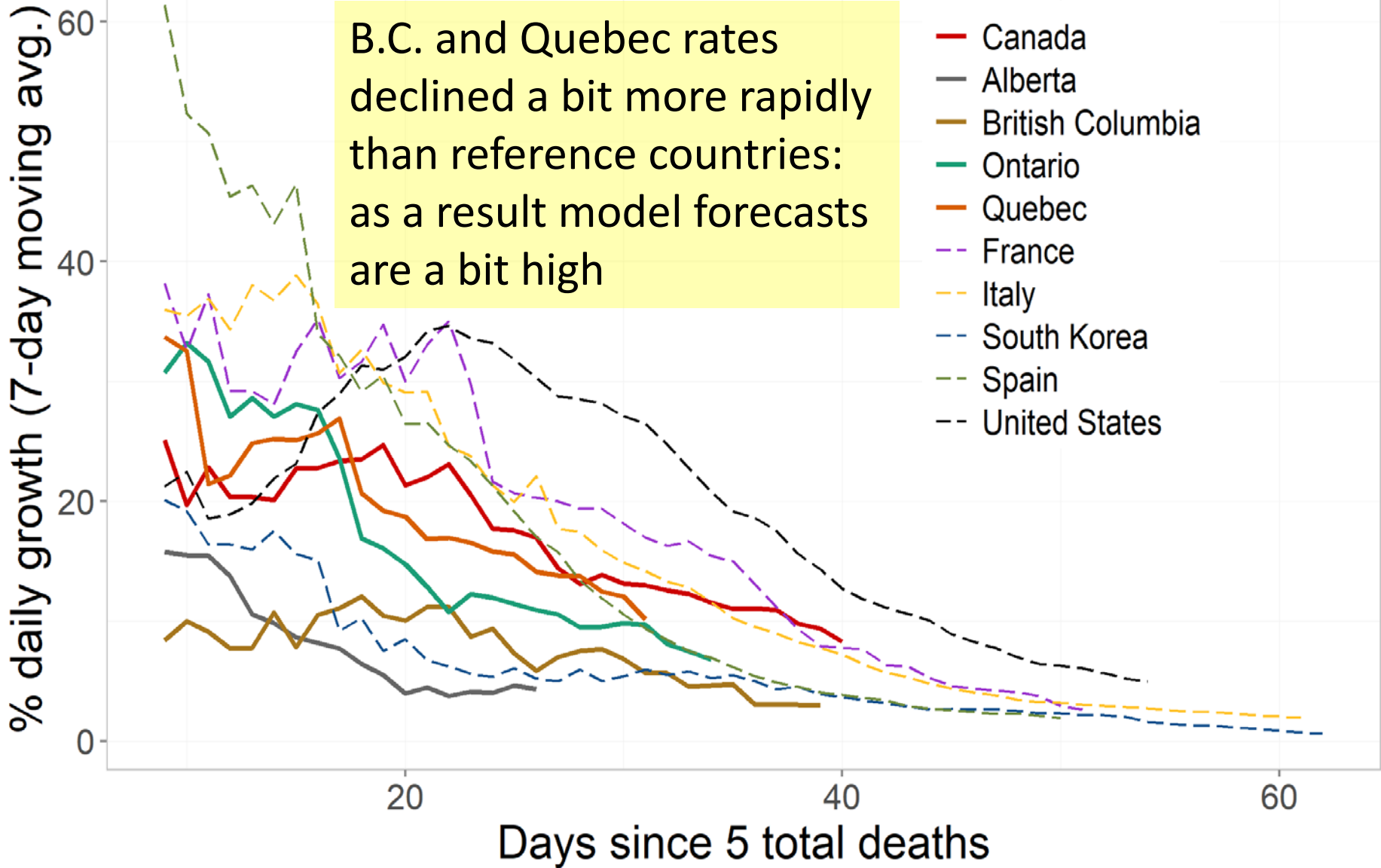
Compare projections made one week apart for B.C.:

Latest projections are more stable (*as actual deaths stabilize*)

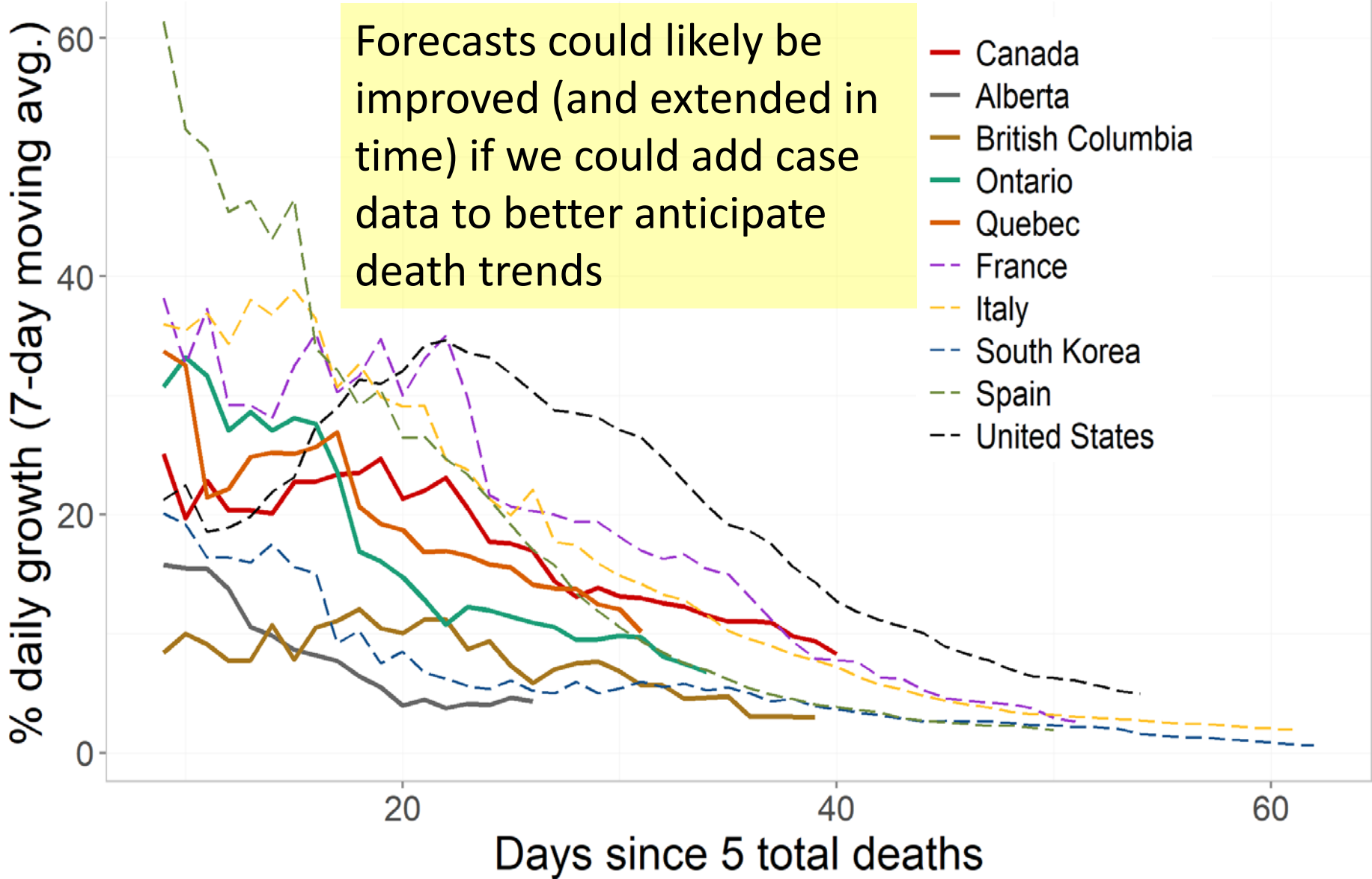
Cumulative death growth rate up to and including **April 17**



Cumulative death growth rate up to and including **April 25**



Cumulative death growth rate up to and including **April 25**



Summary

- Framework established for rapid deployment of daily COVID-19 forecasts
- Positioned to assimilate public health changes in other jurisdictions
e.g. Δr in Spain, Germany, U.S. states, etc.
- Positioned to do local “what-if” analyses
e.g. what if B.C. infection growth rate increased from 3% to 4/5/6/7% on May 1?

Next Steps

1. Refine existing model?

→ *Improve reference curve selection*

→ *Alternative approaches? e.g. Add Cases?*

2. Bring other models into framework

→ *Help represent “between model” uncertainty*

→ *Generate more model-informed scenarios*

→ *Candidate C#/VB/R models in B.C.?*

3. Operationalize the framework?